NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 503

THE EFFECT OF SPRAY STRIPS ON THE TAKE-OFF PERFORMANCE OF A MODEL OF A FLYING-BOAT HULL

By STARR TRUSCOTT

1934

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AERONAUTIC SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Abbreviation	Unit	Abbreviation
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	s	second (or hour)	sec. (or hr.)
Force	F	weight of 1 kilogram	kg	weight of 1 pound	lb.
Power	P	horsepower (metric)		horsepower	hp.
Speed	V	kilometers per hour meters per second	k.p.h. m.p.s.	miles per hour feet per second	m.p.h. f.p.s.

2. GENERAL SYMBOLS

W, Weight $=mg$

g, Standard acceleration of gravity $=9.80665$ m/s² or 32.1740 ft./sec.²

m, Mass $=\frac{W}{g}$

I, Moment of inertia $=mk^2$. (Indicate axis of radius of gyration k by proper subscript.)

μ, Coefficient of viscosity

ν, Kinematic viscosity

ρ, Density (mass per unit volume)

Standard density of dry air, 0.12497 kg-m^{-4}-s^2 at 15° C. and 760 mm; or 0.002378 lb.-ft.$^{-4}$ sec.^{2}

Specific weight of "standard" air, 1.2255 kg/m^3 or 0.07651 lb./cu.ft.

3. AERODYNAMIC SYMBOLS

S, Area

S_w, Area of wing

G, Gap

b, Span

c, Chord

$\frac{b^2}{S}$, Aspect ratio

V, True air speed

q, Dynamic pressure $=\frac{1}{2}\rho V^2$

L, Lift, absolute coefficient $C_L=\frac{L}{qS}$

D, Drag, absolute coefficient $C_D=\frac{D}{qS}$

D_o, Profile drag, absolute coefficient $C_{D_o}=\frac{D_o}{qS}$

D_i, Induced drag, absolute coefficient $C_{D_i}=\frac{D_i}{qS}$

D_p, Parasite drag, absolute coefficient $C_{D_p}=\frac{D_p}{qS}$

C, Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

R, Resultant force

i_w, Angle of setting of wings (relative to thrust line)

i_t, Angle of stabilizer setting (relative to thrust line)

Q, Resultant moment

Ω, Resultant angular velocity

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension (e.g., for a model airfoil 3 in. chord, 100 m.p.h. normal pressure at 15° C., the corresponding number is 234,000; or for a model of 10 cm chord, 40 m.p.s. the corresponding number is 274,000)

C_p, Center-of-pressure coefficient (ratio of distance of $c.p.$ from leading edge to chord length)

α, Angle of attack

ϵ, Angle of downwash

α_o, Angle of attack, infinite aspect ratio

α_i, Angle of attack, induced

α_a, Angle of attack, absolute (measured from zero-lift position)

γ, Flight-path angle

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Langley Memorial Aeronautical Laboratory

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE EFFECT OF SPRAY STRIPS ON THE TAKE-OFF PERFORMANCE OF A MODEL OF A FLYING-BOAT HULL

By Starr Truscott

SUMMARY

The effect on the take-off performance of a model of the hull of a typical flying boat—the Navy PH–1—of fitting spray strips of four different widths, each at three different angles, was determined by model tests in the N.A.C.A. Tank. Spray strips of widths up to 3 percent of the beam improve the general performance at speeds near the hump and reduce the spray thrown. A downward angle of 30° to 45° in the neighborhood of the step seems most favorable for the reduction of the spray. The spray strips have a large effect in reducing the trimming moments at speeds near the hump speed, but have little effect on them at high speeds.

INTRODUCTION

The progress of any craft along the surface of the water at any but the very slowest speeds is accompanied by the formation of waves and spray. If the vessel is of large dimensions relative to its speed the disturbance may be relatively slight, but as the size for a given speed decreases the disturbance increases in relative intensity. In the case of flying boats and seaplanes the formation of waves and spray during the take-off run may assume a particularly inconvenient form. If the hull has a round bottom a sheet of water may follow right up the sides and curl over inboard until at the stern the two curls may meet to form a high roach (reference 1). If the hull has a stepped V bottom, with sharp chines where the bottom meets the sides, the tendency seems to be for the water to run up the V bottom in a sheet and to be carried well beyond the beam of the hull in a trajectory by the momentum acquired under the bottom. This sheet of water usually rises high and breaks up into smaller masses that may be picked up by a propeller, or by the wind, and carried at high speed through the propeller or into parts of the airplane structure. Although no immediate damage may result, there is always danger of it (references 1 and 2).

An obvious method of suppressing the spray is to fit strips, or battens, along the chine of the hull to catch the rising sheets of water and deflect them downward. Such strips, or battens, are referred to as "mudguards" in what appear to be the earliest tests of models in which they were incorporated (references 3, 4, and 5). These strips may be either narrow fins projecting from the chines or rectangular, or triangular, strips on the bottom just inside the chines. (See secs. L and M, reference 1, p. 32.)

An equally obvious method is to build the form of the strips into the bottom, giving the section of the bottom just inboard of the chine a curve to which the outboard tangent is either horizontal or slopes downward. This construction provides a deflecting surface in the bottom and does away with any fitted-on construction, but at the same time necessitates the bending of frames and plating and increases the difficulty of either plating or planking the bottom.

The straight V bottom with a spray strip in the form of a projecting fin at the chine appears to have the virtue of simplicity, but no published information has been found that gives a clue to the proper width and angular setting of such a strip to obtain the maximum reduction in spray thrown or tells how the width and angular setting of the spray strip affect the performance on the water. Each user has accordingly followed his own ideas as to the widths and angles to be given to the spray strip.

The purpose of the tests described in this report was to determine the effect of fitting spray strips of various widths and at various angles on a model of the hull of a flying boat that had a good performance on the water and in the air by comparing the results of tests in those conditions with tests made with no spray strips in place. A ⅙-full-size model of the Navy PH–1 flying boat was available for this work.

The tests were confined to the one model. It has a form of bottom that may be said to be generally similar to that found on most American flying boats. This model was tested with no spray strips and with spray strips of four different widths, each at three different angles at the step. In each condition the model was tested both free to trim and at three angles of fixed trim.

All the tests were made in the N.A.C.A. Tank at Langley Field, Va. The work of testing and working up results was done at intervals in 1931, 1932, and 1933.

APPARATUS AND METHODS

The model.—The model was the one used in previous tests to determine the effect of "flutes" in the bottom and of "hooks" on the step, described in reference 6. It was constructed of pine from lines and offsets supplied by the Hall-Aluminum Aircraft Corporation and was made to a scale of 2 inches=1 foot, or ⅙ full size. A small hook on the step, which is present on the full size, was omitted on the model. The surface of the model was painted with several coats of Navy gray enamel and was rubbed down between coats to give a smooth finish. Check measurements made on a surface plate, using height gages, indicated that the dimensions were generally accurate to within ±0.01 inch. The form and dimensions of the model are shown in figure 1. Detailed particulars are as follows:

	Model	Full size
Length, over-all (o.a.)	96.58 inches	48 feet 3½ inches.
Length, forebody (to step)	48.48 inches	24 feet 2⅞ inches.
Length, to stern post	76.61 inches	38 feet 3¹¹⁄₁₆ inches.
Beam, over designed chine	16.69 inches	8 feet 4⅛ inches.
Dead rise at step	22½°	22½°.
Designed trim	0°	0°.
Gross load	69.1 pounds	14,910 pounds.
Get-away speed	35.5 feet per second	86.9 feet per second.
Center of buoyancy (c.b.) abaft bow	40.44 inches	20 feet 2⅝ inches.
Center of gravity (c.g.) above keel	16.62 inches	8 feet 3¹¹⁄₁₆ inches.
Center of gravity forward of step	8.04 inches	4 feet 0¼ inch.
Angle of keel forward of step to base line	1°	1°.
Angle of keel aft of step to base line	5½°	5½°.
Angle of keel aft of stern post	14°	14°.
Depth of step (no hook)	0.56 inches	3⅜ inches.

Linear ratio of model to full size	1:6
Forebody:	
Percentage of over-all length	50. 2
Percentage of length to stern post	63. 2
Beam:	
Percentage of over-all length	17. 3
Percentage of length to stern post	21. 8
Percentage of length of forebody	34. 4
Center of buoyancy abaft bow:	
Percentage of over-all length	41. 8
Percentage of length to stern post	52. 8
Percentage of length of forebody	83. 3
Center of gravity above keel:	
Percentage of over-all length	17. 2
Percentage of length to stern post	21. 7
Percentage of length of forebody	34. 3
Center of gravity forward of step:	
Percentage of over-all length	8. 3
Percentage of length to stern post	10. 5
Percentage of length of forebody	16. 6
Depth of step: Percentage of beam	3. 37

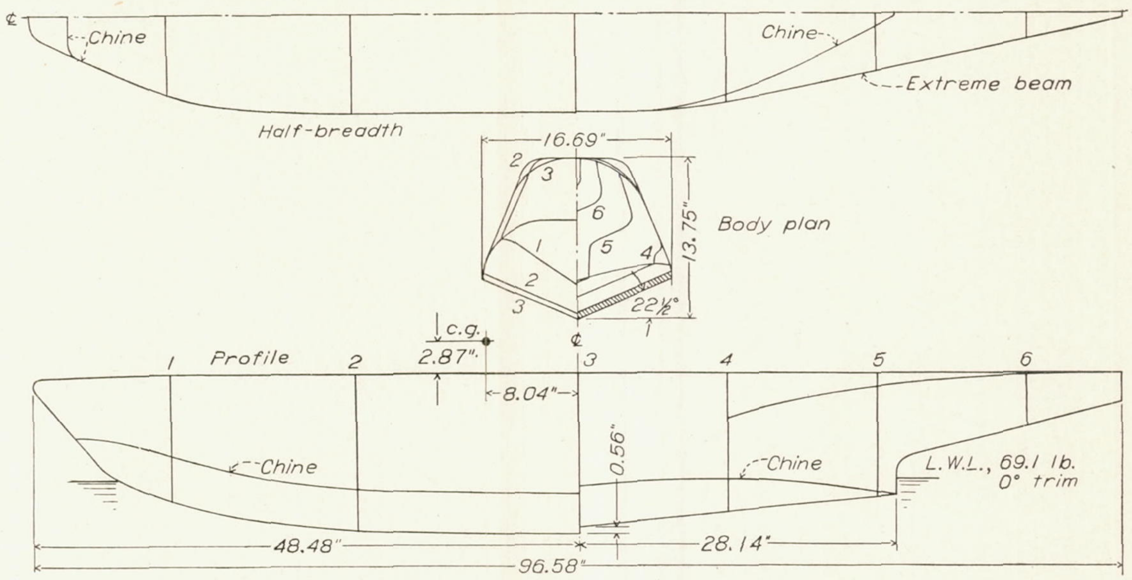


FIGURE 1.—Principal dimensions of the model of the hull of the PH-1 (N.A.C.A. Tank Model 1).

The spray strips.—The spray strips were made of sheet brass 0.049 inch thick and were secured to the model by small brass wood screws passing through lugs at about 3-inch centers. These lugs were bent up to apply to the sides of the model above the chines. The dimensions and the angular settings of the spray strips at each station are shown on figure 2.

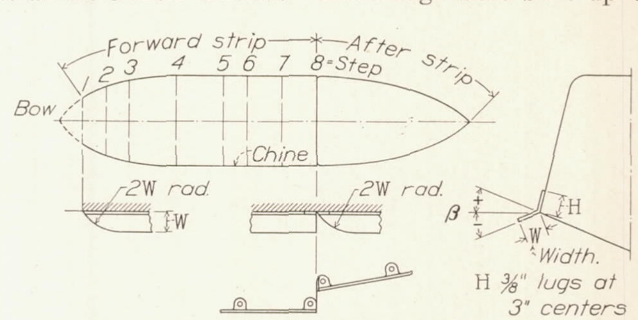


FIGURE 2.—Spray strips—arrangement and details.

While the model was on the surface plate the angle of the spray strip to the horizontal was determined at each station along the hull by applying a bubble inclinometer to the strip. Between stations the angle was

adjusted by eye to give a smooth fair curve from end to end.

After a spray strip had been adjusted to the proper angles and width the space between the lugs was filled and carefully smoothed with plasticine. This procedure was unnecessary as far as resistance at high speeds was concerned, for the area covered with plasticine came out of the water at relatively low speeds, but it was thought desirable to prevent the formation of any jets or disturbances that might persist after the model was well under way.

The original flying boat from which the model was derived has a spray strip the width and angles of which were determined primarily to reduce resistance and spray and secondarily from its use as a structural component of the hull and as a joint between the bottom and side plating. Accordingly, the first spray strips tested were 0.156 inch wide, corresponding to those of the original hull, and were set at the corresponding angles. From observation of the manner in which these strips deflected the spray a second set of angles for the strips was derived, generally sharper downward angles and with the angle at the step −30°. The angle at the step was increased to −45° for a third set of tests.

Runs with the first spray strips used showed that the strip aft of the step had little effect on spray and that its effect on resistance was lost as soon as the model began to plane. It was fitted on succeeding tests, however, in order to make all the results comparable.

The towing gear.—The heavy towing gate and gear described in reference 6 were used with the "hydrovane" method of applying the lift simulating that of the wings of the full-size machine. The model was secured to the gear in such a manner as to permit it to trim about the center of gravity shown in figure 1. The method of testing was that described as the specific, or hydrovane, method in reference 6.

Photographs.—Photographs were taken of the model during each test run, using two cameras and making simultaneous exposures. The cameras were mounted to take one photograph from the port forward quarter and one from the port beam. The method of taking these photographs was being developed while the work on this model was in progress and many of the earlier photographs were unsatisfactory. For this reason the photographs reproduced herein are not as uniform as those obtained after the method was perfected.

Program of tests.—The program of tests was the same for each arrangement of spray strips on the model. It included runs free to trim at speeds up to about 75 percent of get-away speed, runs at fixed trims of 4° and 6° from about 35 percent get-away speed to get-away speed, and runs at 8° fixed trim from about 35 percent get-away speed to about 75 percent get-away speed. The initial displacement of the model was always 69.1 pounds and the get-away speed, 35.5 feet per second.

Presentation of results.—The data from the various runs are very completely expressed in the curves that form figures 3, 4, 5, and 6. On each of these curves the width and angle of the spray strip at the step are shown.

A selection of typical photographs from the free-to-trim runs is presented as figure 7 with the data necessary for their identification.

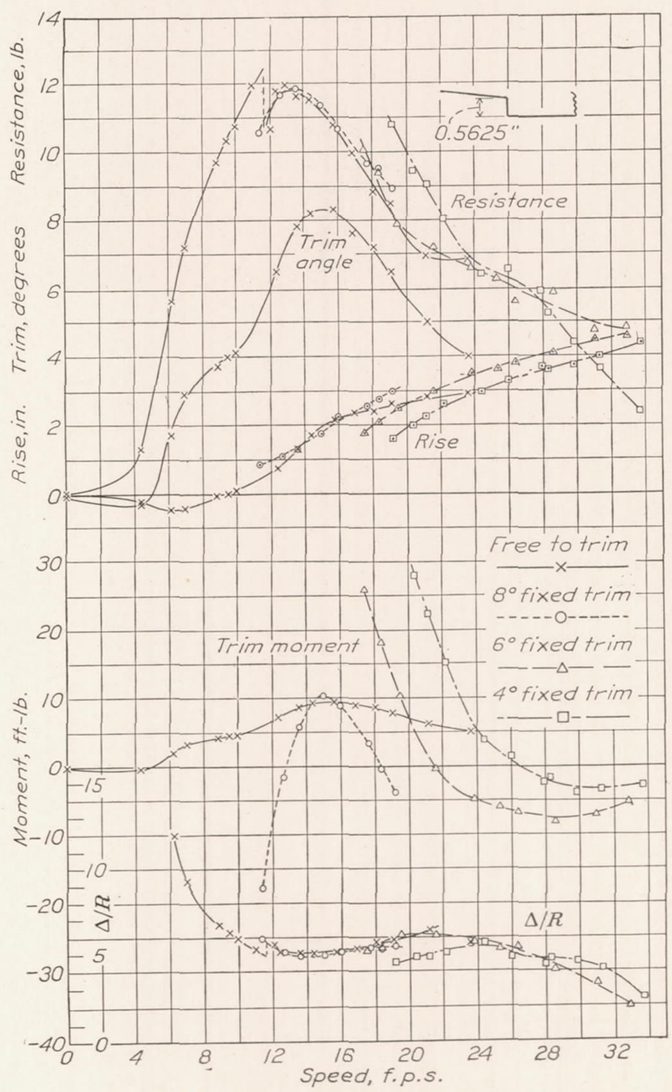
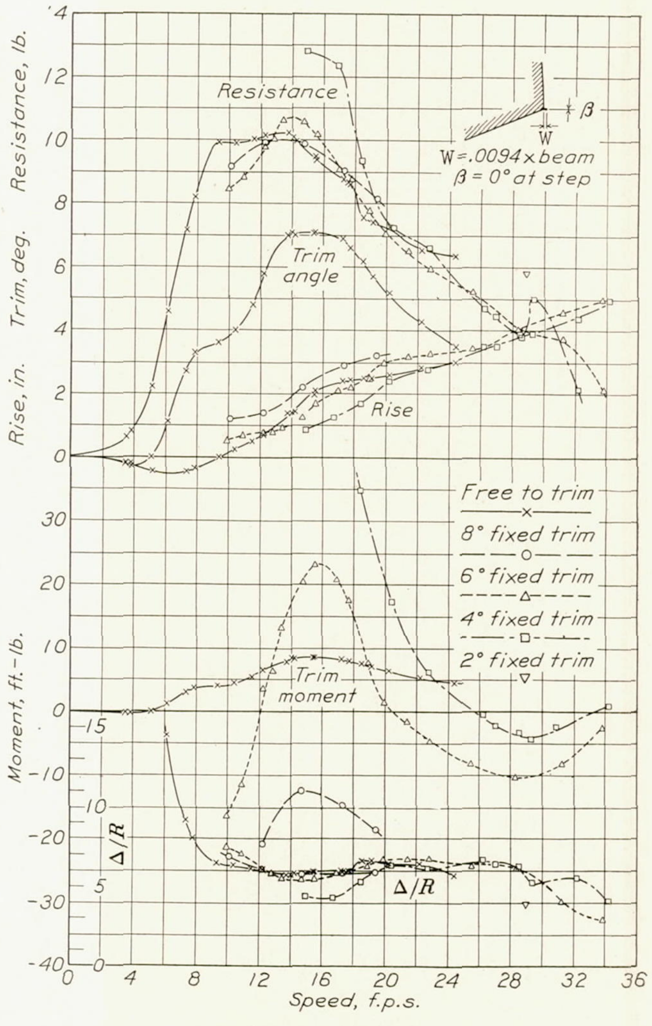


FIGURE 3.—Performance curves of Model No. 1 with no spray strips.

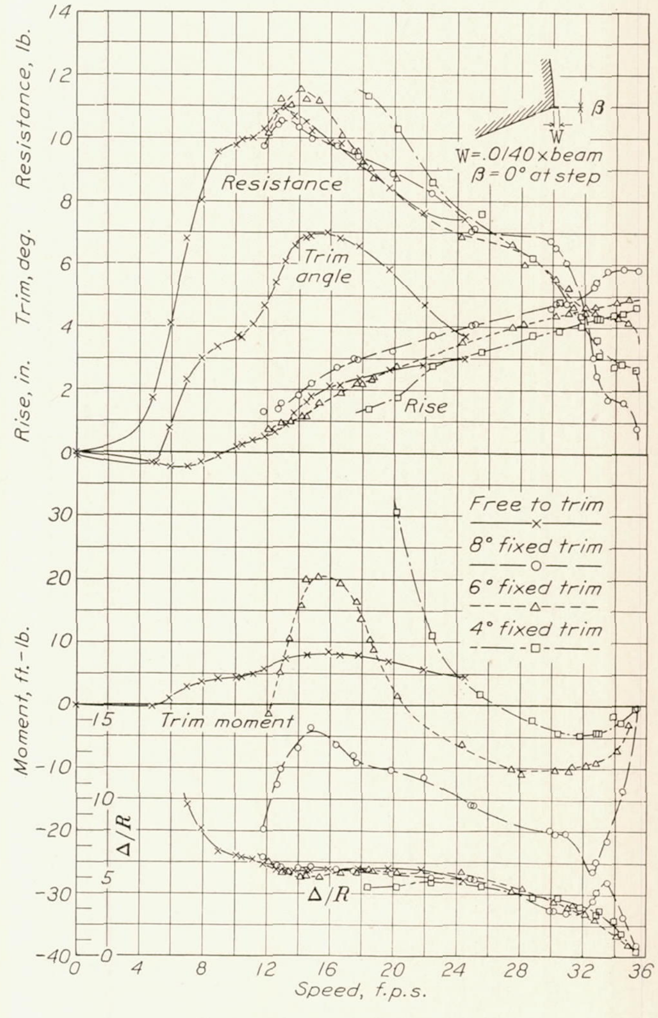
Precision.—It is believed that the results from which the curves were prepared were correct within the following limits:

Load, pounds	±0.3
Resistance, pounds	±0.1
Speed, feet per second	±0.1
Angle, degrees	±0.1
Moment, foot-pounds	±1.0
Rise, inches	±0.1

At some places the faired curves would not pass through the points with this accuracy because the model was running unsteadily. The position selected for the curve is considered to be very close to the proper value.

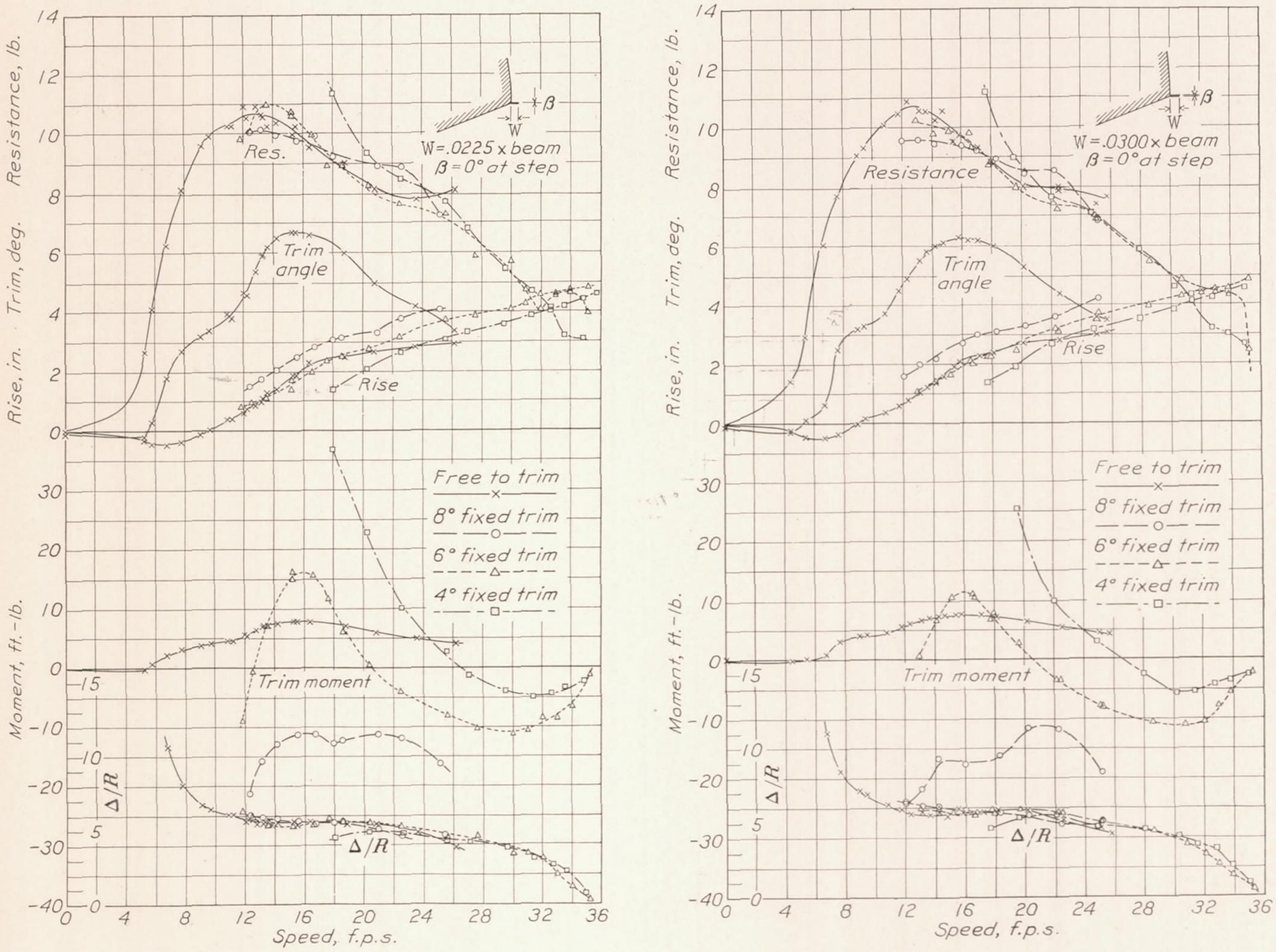


(a) Width 0.156 inch (0.0094 beam).



(b) Width 0.234 inch (0.0140 beam).

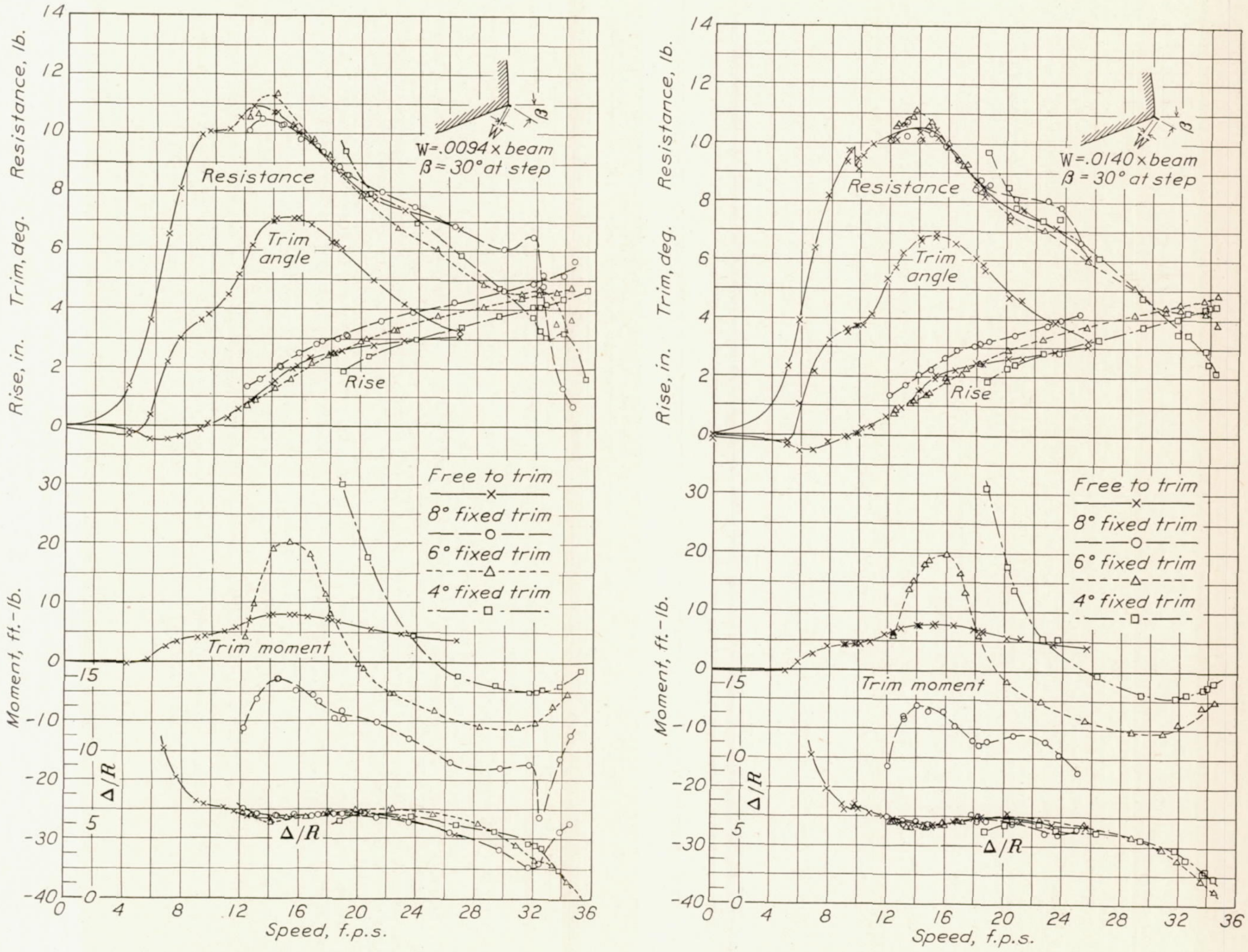
FIGURE 4.—Water performance curves with spray strips horizontal.



(c) Width 0.375 inch (0.0225 beam).

(d) Width 0.500 inch (0.0300 beam).

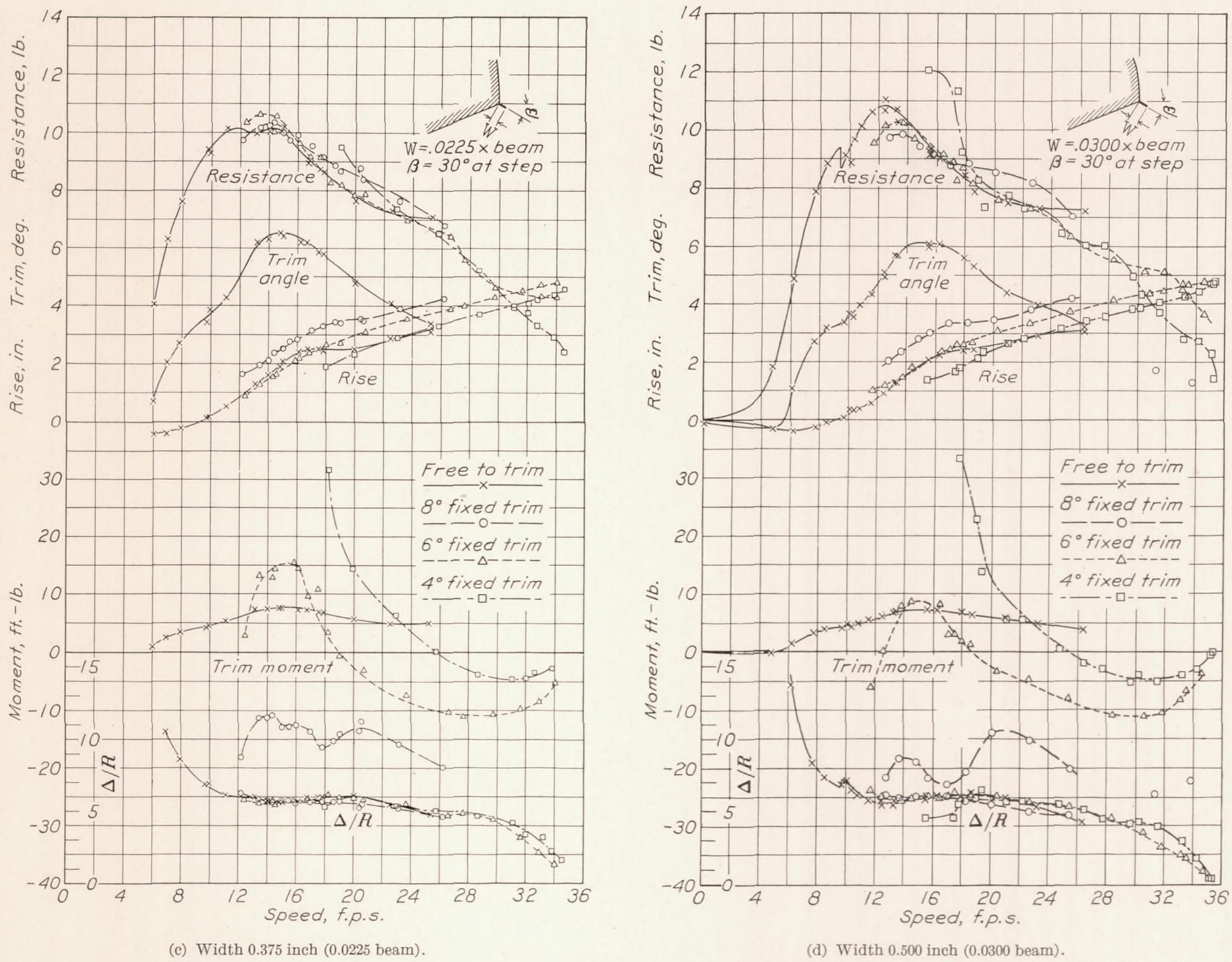
FIGURE 4.—Water performance curves with spray strips horizontal.



(a) Width 0.156 inch (0.0094 beam).

(b) Width 0.234 inch (0.0140 beam).

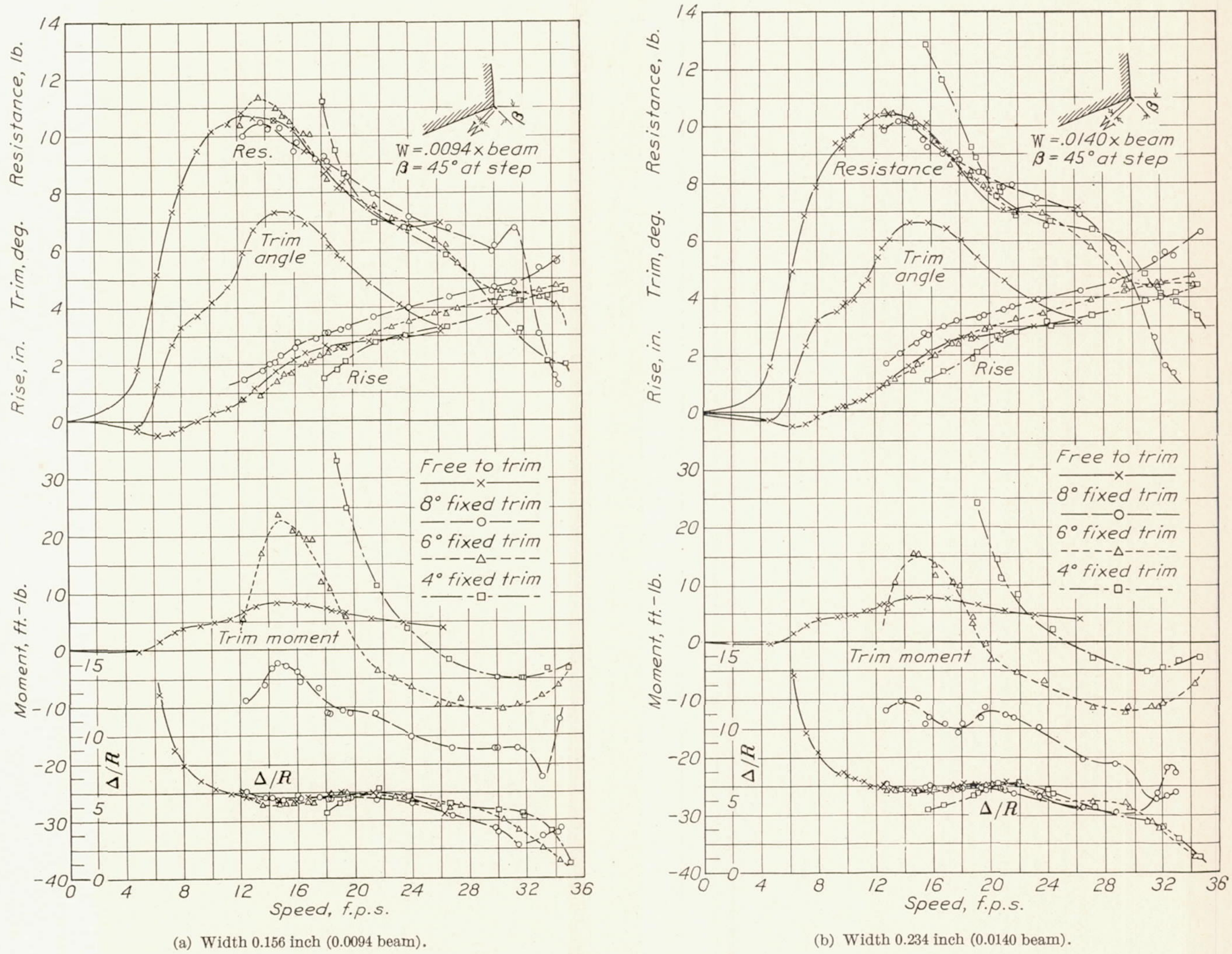
FIGURE 5.—Water performance curves with spray strips 30° down.



(c) Width 0.375 inch (0.0225 beam).

(d) Width 0.500 inch (0.0300 beam).

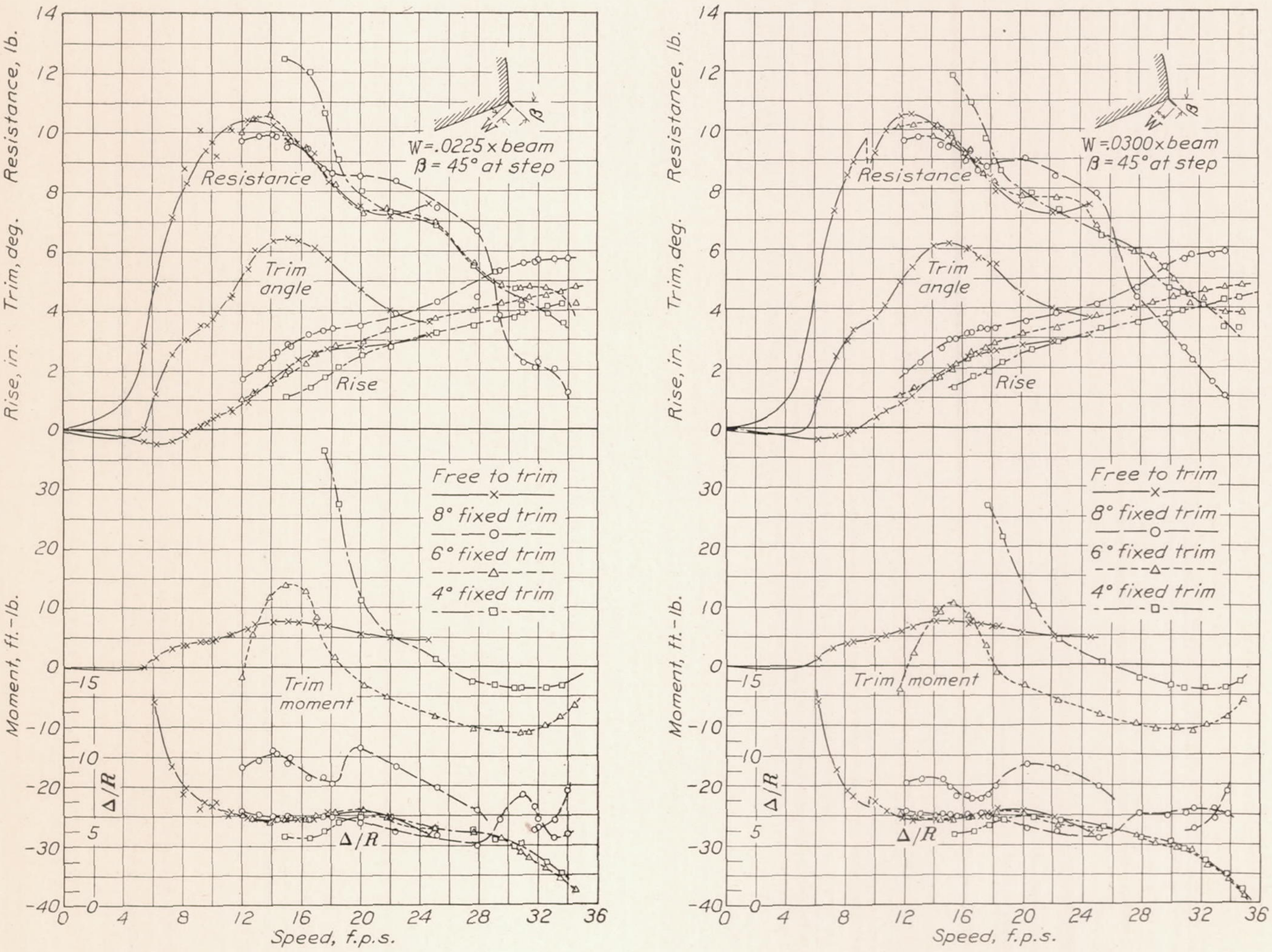
FIGURE 5.—Water performance curves with spray strips 30° down.



(a) Width 0.156 inch (0.0094 beam).

(b) Width 0.234 inch (0.0140 beam).

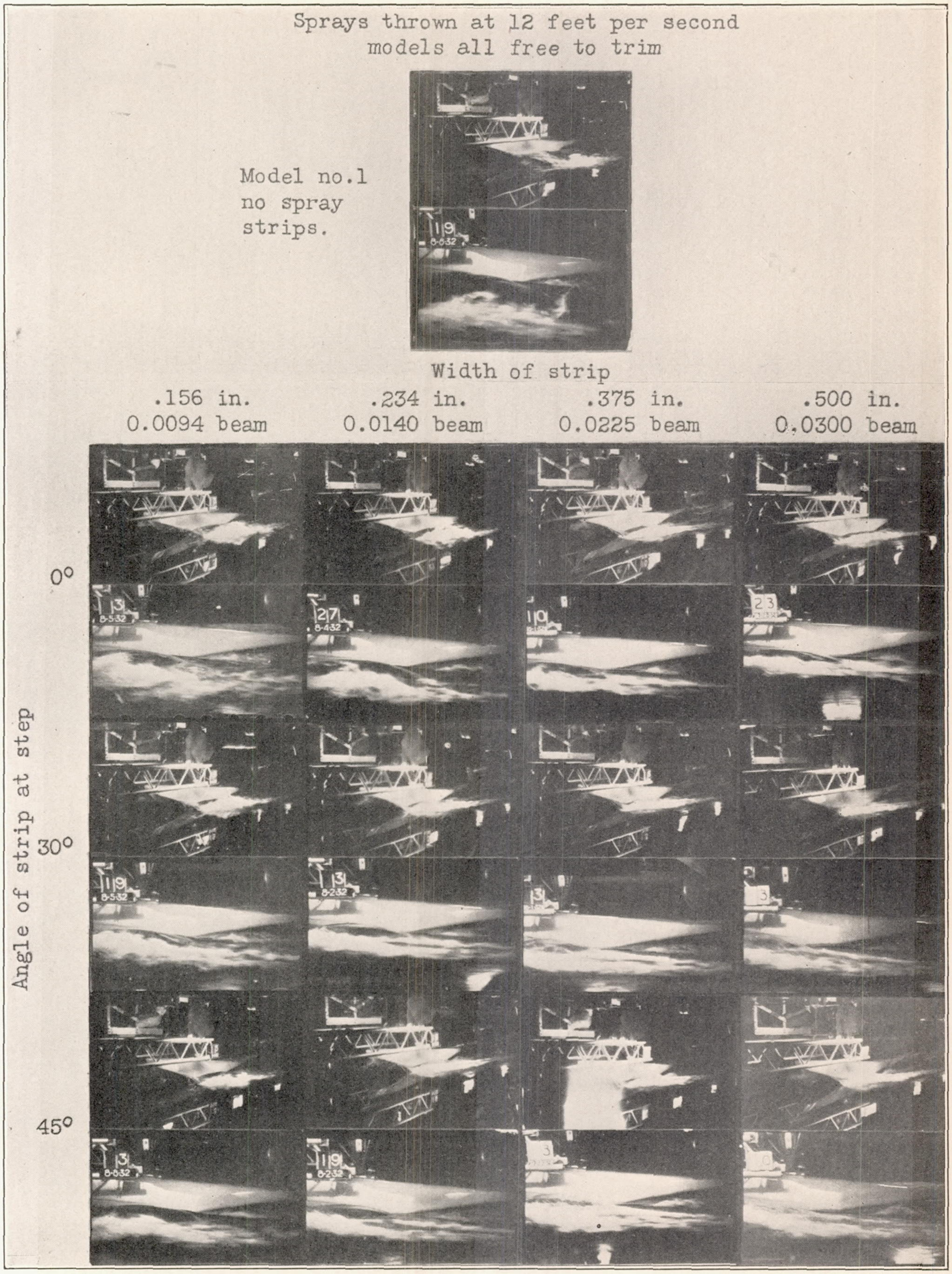
FIGURE 6.—Water performance curves with spray strips 45° down.



(c) Width 0.375 inch (0.0225 beam).

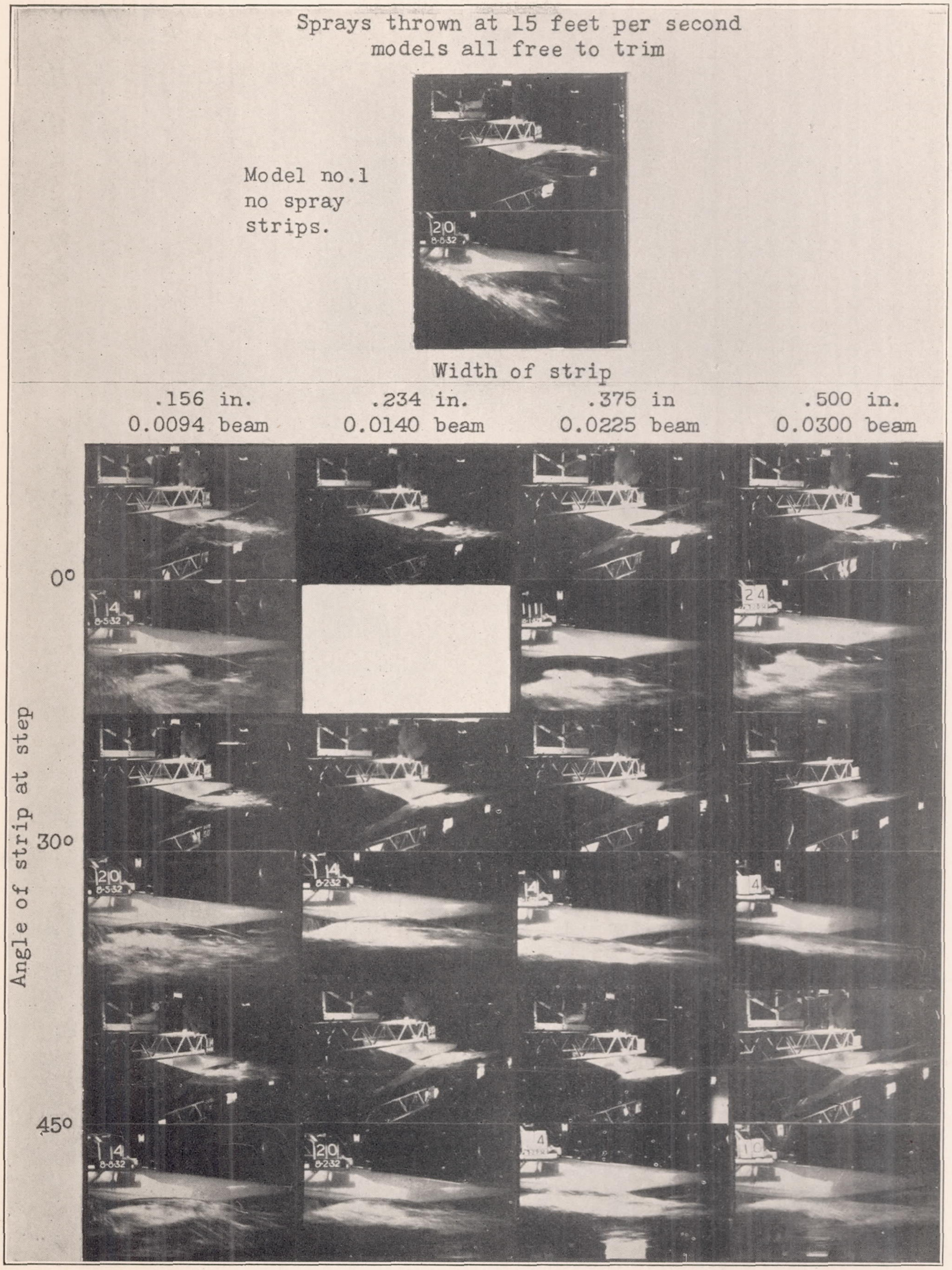
(d) Width 0.500 inch (0.0300 beam).

FIGURE 6.—Water performancee curves with spray strips 45° down.



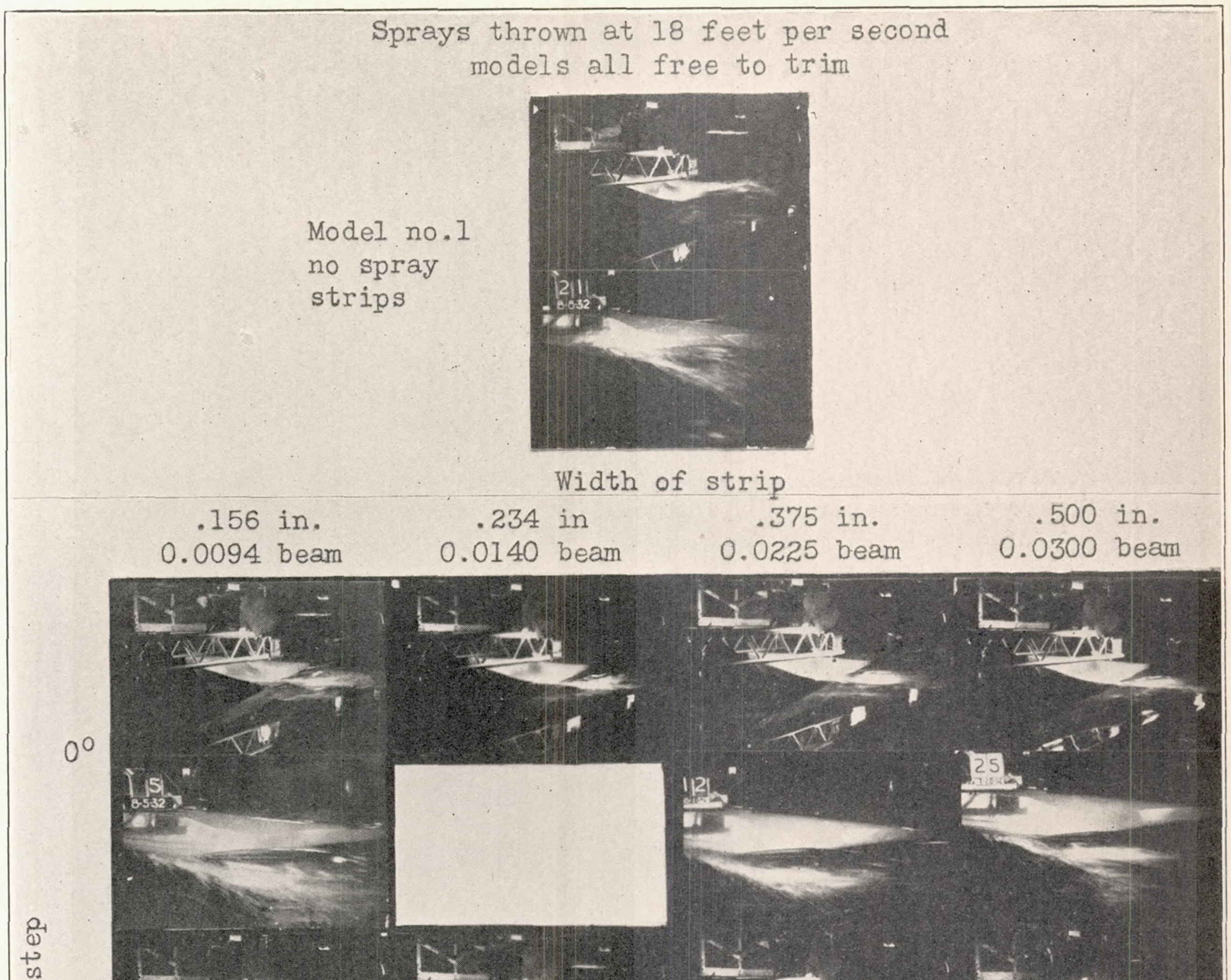
(a) Free to trim at 12 feet per second.

FIGURE 7.—Effect of width and angle of spray strips on spray.



(b) Free to trim at 15 feet per second.

FIGURE 7.—Effect of width and angle of spray strips on spray.



(c) Free to trim at 18 feet per second.

FIGURE 7.—Effect of width and angle of spray strips on spray.

DISCUSSION OF RESULTS

It is of interest to consider the results of the tests as they show the effects of the various changes on (1) spray, (2) rise, (3) resistance, (4) moments.

Spray.—The effect on the spray can be determined only by observation. Part of this observation is presented in the photographs of figure 7 which show only the spray, free to trim, at speeds of about 12, 15, and 18 feet per second for the different arrangements of the spray strips and, for comparison, the spray from the model without spray strips. The photographs for each nominal speed are grouped to bring out the effect of changing the angle of the strip and its width. It should be remembered that runs cannot be regularly repeated at exactly the same speed. The actual speeds at which the pictures were made are shown in the following table:

ACTUAL SPEEDS CORRESPONDING TO NOMINAL SPEEDS OF MODEL FOR PICTURES OF FIGURES 7 (a) TO 7 (c)

Figure 7 (a), nominal speed feet per second 12
Actual speed, no strips feet per second 12

	Actual speeds			
Width of strip, inches	0.156	0.234	0.375	0.500
Angle of strip (degrees):	*Feet per second*	*Feet per second*	*Feet per second*	*Feet per second*
0	12.0	12.3	11.7	12.1
30	12.0	11.7	11.7	12.0
45	12.0	11.9	12.0	12.3

Figure 7 (b), nominal speed feet per second 15
Actual speed, no strips feet per second 15

	Actual speeds			
Width of strip, inches	0.156	0.234	0.375	0.500
Angle of strip (degrees):	*Feet per second*	*Feet per second*	*Feet per second*	*Feet per second*
0	14.8	14.9	14.6	15.1
30	14.7	14.7	14.0	15.5
45	15.0	15.0	14.4	15.4

Figure 7 (c), nominal speed feet per second 18
Actual speed, no strips feet per second 17.5

	Actual speeds			
Width of strip, inches	0.156	0.234	0.375	0.500
Angle of strip (degrees):	*Feet per second*	*Feet per second*	*Feet per second*	*Feet per second*
0	18.2	17.9	17.5	18.1
30	17.7	17.6	17.3	18.3
45	18.0	18.0	17.9	18.7

The spray thrown is a maximum in the range of speeds covered by the photographs, being less below 12 and above 18 feet per second. With this model the ability to reduce the spray between 12 and 18 feet per second is the test of the efficacy of a spray strip. It will be seen that at each speed the spray strips have been effective in reducing the spray and that this effect increases with increase in the width of the strip and with the increase of the downward angle at the step. In general, the effect of the spray strips is to cut down the distance to which the spray is thrown on leaving the chine, and the sharper the downward angle the closer to the hull the spray is returned to the water.

If this return takes place too quickly, however, the spray may encounter a rising wave or a rebound may follow from the surface of the water with the appearance of a second rising sheet of water at a short distance out from the hull. In some cases this second spray will be even more broken than the original from the chine without a spray strip, and may extend as far or even farther. As a rule, however, the wider spray strips at the larger angles are more effective than the narrower ones or those at the smaller angle.

Rise.—In general, the spray strips have but slight effect on the rise.

The change in the rise, compared with that of the bare model, caused by fitting the spray strips is greatest at 8° fixed trim. At 15 feet per second the increase is about 25 percent for the flat strip (0°) at the narrowest width (0.156 inch), and becomes steadily larger for increasing width of strip and increase of angle until at maximum angle (45°) and width (0.50 inch) it reaches 60 percent. The rise of the plain model is only 1.8 inches and the maximum change produced by adding the spray strip is 1.00 inch.

At 4° fixed trim and 20 feet per second the rise of the plain model is 1.9 inches and the change produced by adding the spray strips varies from 0 to a maximum of 30 percent with the maximum angle and width.

With these exceptions the change in rise produced by adding the spray strip never exceeds 10 percent of the rise of the plain model and usually remains less than the ±0.1-inch precision of the readings. Probably the effect on the rise of a full-size machine of fitting spray strips would not be perceived as such by the occupants.

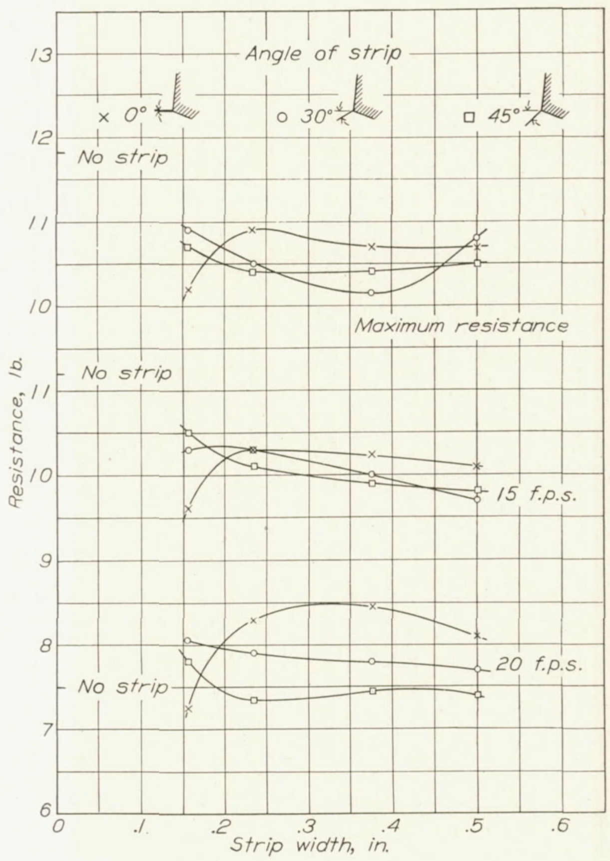
Resistance.—The effects of the spray strips and of the various changes in width and angle on resistance can be seen from the original curves of figures 3, 4, 5, and 6. With so many curves to be compared, a superposition of them becomes confusing. A somewhat clearer idea of the effects of the changes can be obtained from the curves of figure 8. In these curves the resistances and moments at 15, 20, and 30 feet per second are plotted against the respective widths of the strips with the angles of the strips as a parameter. The resistances and moments of the hull without strips are indicated for each speed and trim angle.

From figure 8 (a) it appears that the maximum resistance free to trim with no spray strip is 11.8 pounds, but with any of the spray strips the maximum resistance is uniformly less and, with the spray strip at 30° down and 0.0224 beam (0.375 inch) wide, even as low as 10.15 pounds.

At each speed the curves seem to follow the same generally characteristic trend. The curve for the

horizontal strip is lower than the others at the narrowest width, 0.0094 beam (0.156 inch), and rises rapidly to greater than the others for 0.0140 beam (0.234 inch). From this magnitude it decreases and approximates the rising curves of the others at the greatest width, 0.030 beam (0.50 inch). The curves for the 30° and 45° angles lie relatively closer together and generally lower than the first, but frequently tend to rise as the width increases.

An inspection of the curves of figure 8 shows that the general effect of the addition of the spray strips is



(a) Free to trim at maximum resistance and at 15 and 20 feet per second.

FIGURE 8.—The effect of width of spray strip on resistance.

to reduce the resistance at speeds near the hump and somewhat later, but that, as the get-away speed is approached, the resistance with the spray strips becomes first about the same as that without spray strips (see the curves for 20 feet per second), and then becomes somewhat greater for the remainder of the course, as shown in the curves for 30 feet per second. It will be noted, however, that at 6° fixed trim and 30 feet per second the 30° and 45° spray strips give resistances lower than the plain model except at the greatest width, where they just equal it.

Moments.—One of the effects of the spray strips is the production of relatively large changes in the trimming moments at fixed trim, as is shown in figures 8 (b) to 8 (d). At first sight it appears unlikely that the addition of a narrow strip along the chine could have such large effects on the moments. The cause is evident, however, when one inspects the diagrams showing the distribution of pressures over the bottom of planing surfaces that were shown by Sottorf in reference 7. On reference to figures 22 and 26 of his paper it will be observed that the transverse distribution of the pressure on a plain V bottom having a dead rise of 24° (approximately the same as in model 1, 22½°) may be expected to show a fairly uniform slow decrease from the keel to just at the chine where a rather abrupt drop occurs. If a downward hook is fitted just inboard at the chine the transverse distribution shows a sudden and violent peak under that hook, obviously caused by the change in direction of the water flowing up the bottom. Similarly, the fore-and-aft distribution reflects the presence of the deflecting form by showing fore-and-aft peaks of pressures reaching considerably greater magnitudes than any found in the plain V bottom.

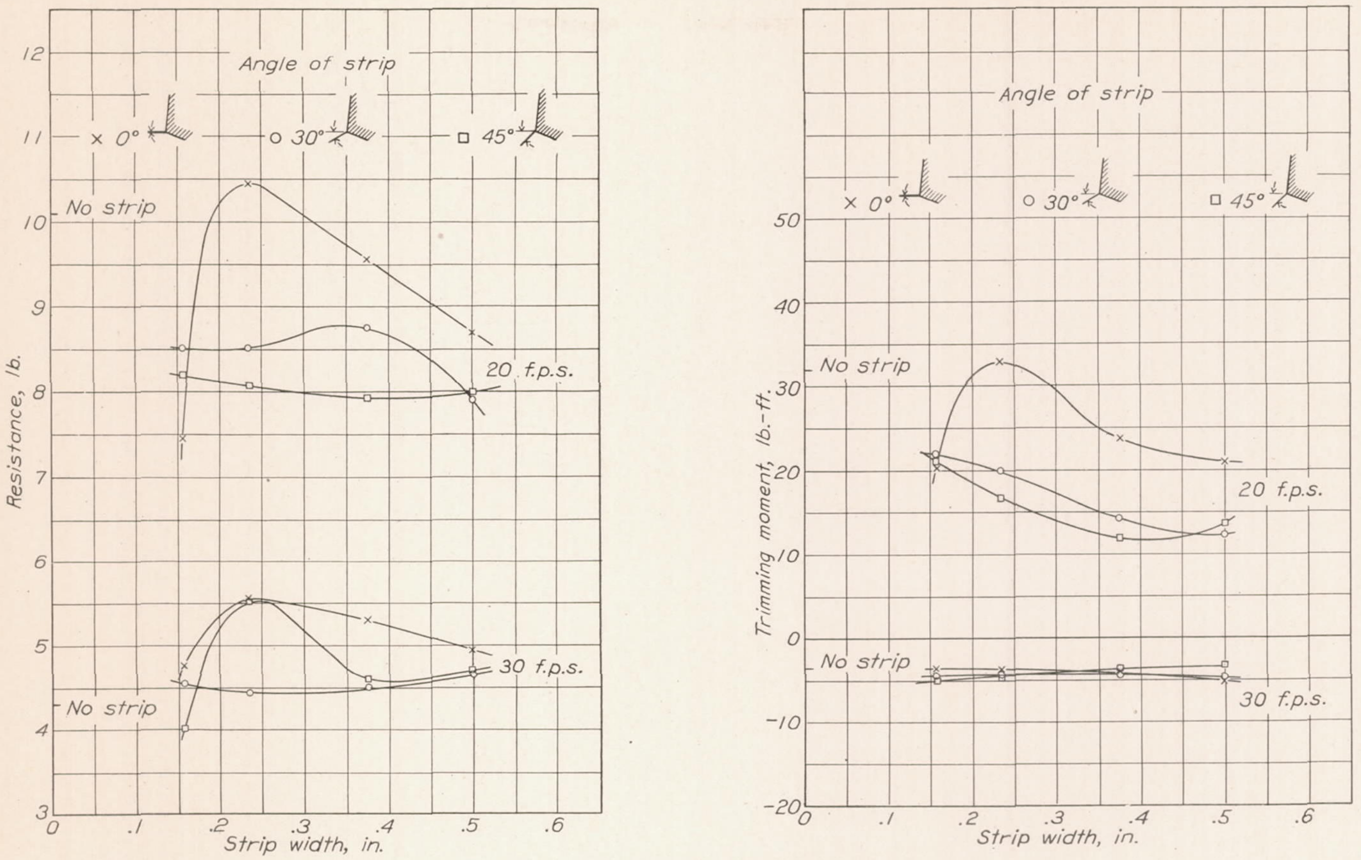
These peaks of pressure produced by the deflection of the streams flowing from the bottom of the hull cause a change in the magnitude and position of the resultant of the pressures on the bottom. It seems only natural to expect that for a given speed a somewhat greater hydrodynamic lift will be generated with the deflecting form than with the plain form. This supposition is confirmed by the changes in the rise at the different speeds. The change in the position of the resultant of the lift and resistance will also cause a change in the moment of the resultant about the center of gravity, or a change in the trimming moment.

Sottorf's tests developed the effects of relatively large changes in the form of the bottom. These tests on the model of the PH–1 show that the same general effect may be produced by very narrow strips along the chine.

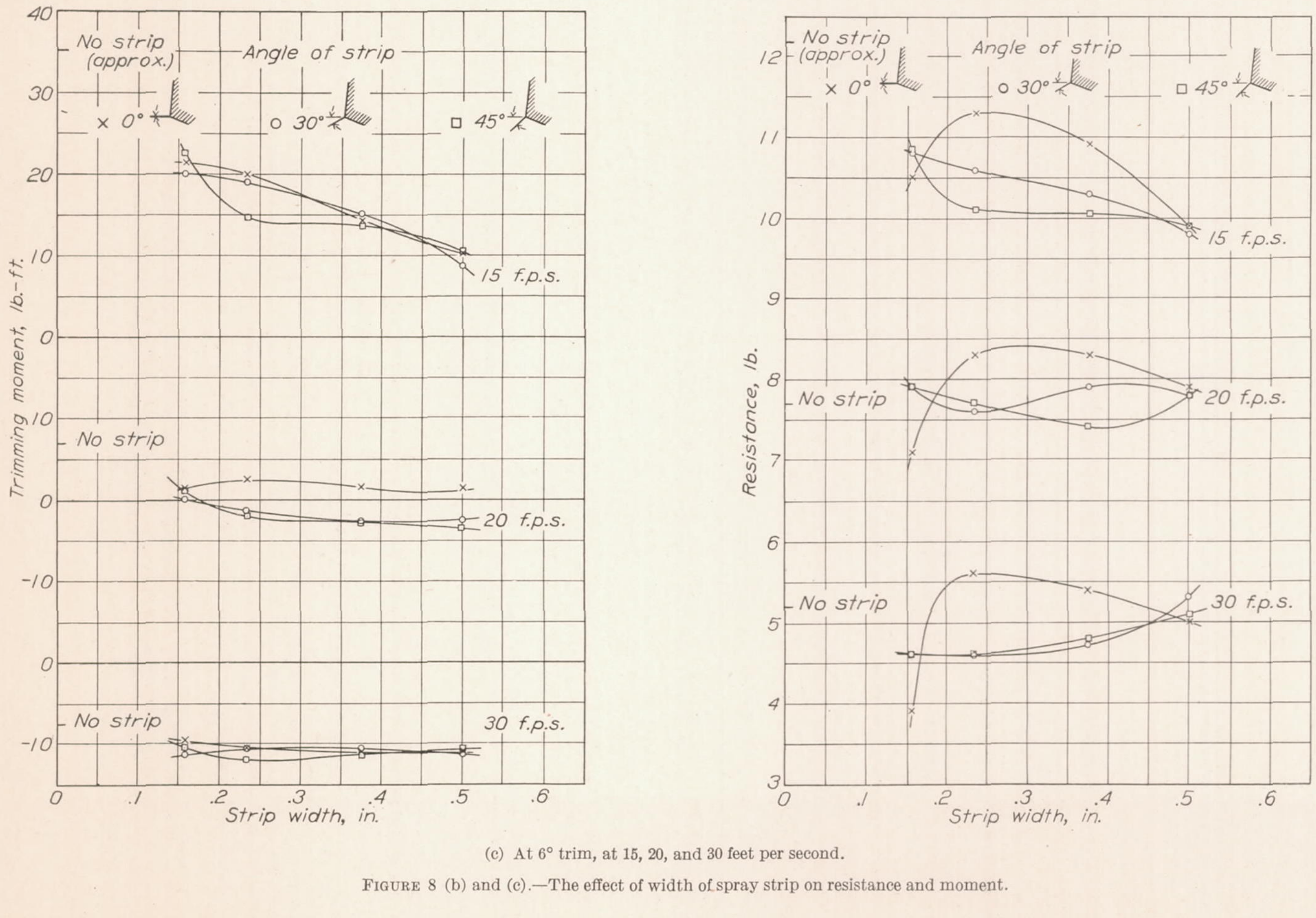
One would expect the impact forces on the bottom with a deflecting form to rise to considerable magnitude—about under the vertex of the curve. On a plain V bottom with spray strips the extreme pressure would be expected right at the chine. If the load on the spray strips exceeded the amount that could be supported by them, they probably would bend and release the pressure. This action would not occur if the deflecting surface was built into the bottom.

An inspection of the curves of figure 8 discloses that the spray strip generally produces negative trimming moments. At 15 feet per second the negative moments are greatest for 6° and 8° trim and grow larger with increasing width of strip. They also are larger for the larger trim.

At 20 feet per second the data make it possible to compare the moments at 4°, 6°, and 8° trim. Here the negative moments produced by the addition of the spray strips seem to lessen as the trim angle increases, but again they increase as the width of the strip increases, although not so rapidly as for 15 feet per second.



(b) At 4° trim, at 20 and 30 feet per second.



(c) At 6° trim, at 15, 20, and 30 feet per second.

FIGURE 8 (b) and (c).—The effect of width of spray strip on resistance and moment.

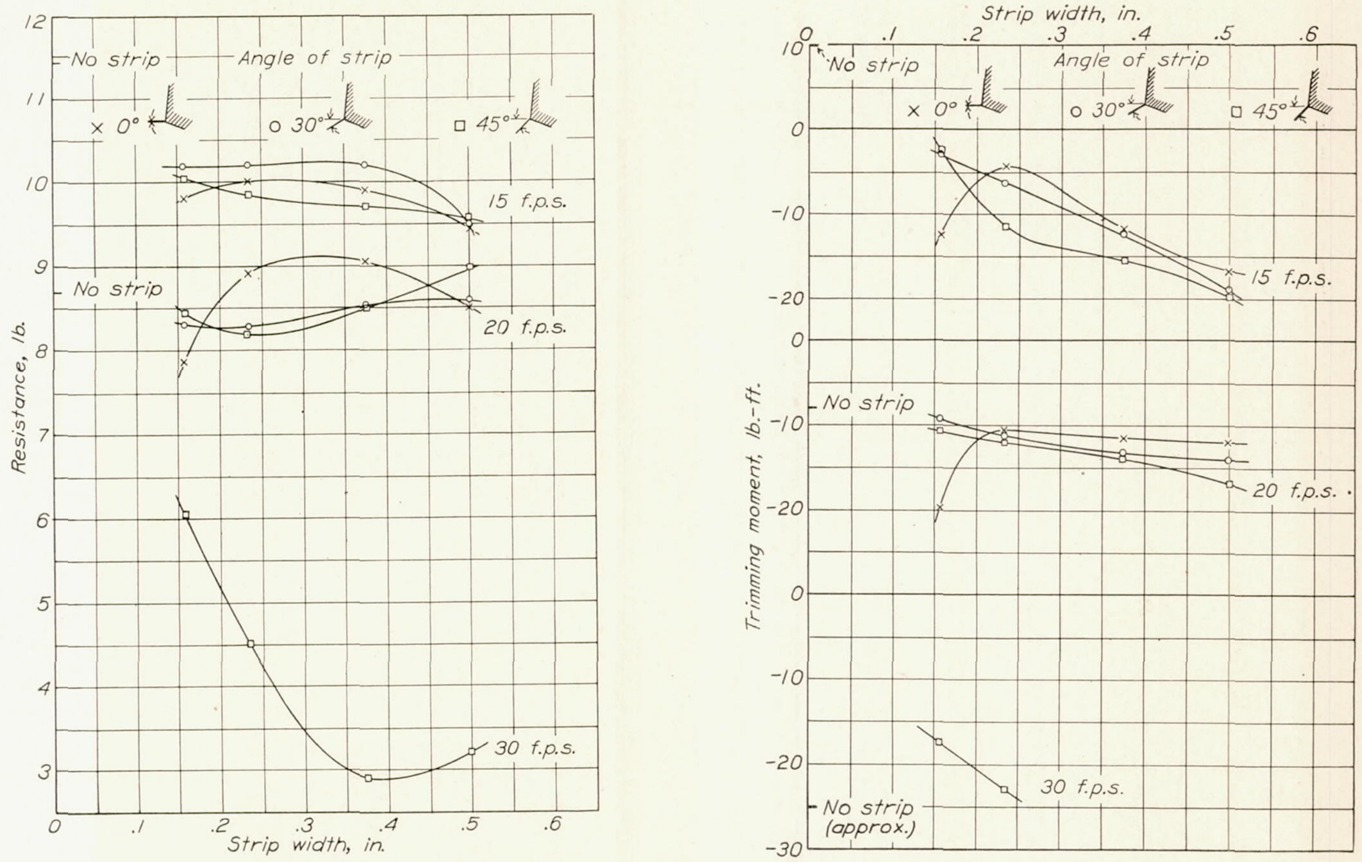


FIGURE 8 (d).—The effect of width of spray strip on resistance and moment. At 8° trim, at 15, 20, and 30 feet per second.

At 30 feet per second the effect of any one of the spray strips on the moments for 4° and 6° trim appears

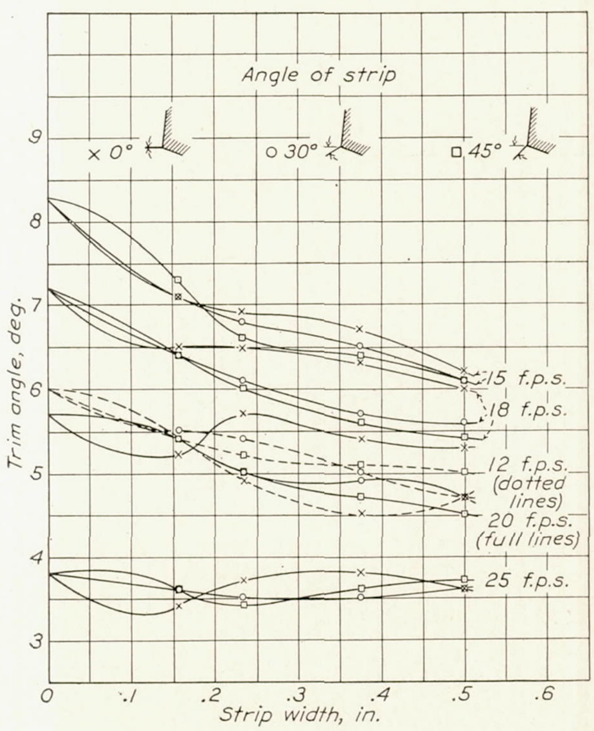


FIGURE 9.—Effect of width and angle of spray strips on free trim.

to be about the same as the others, and any effects of differences in width and angle seem to disappear. An attempt was made to approximate the corresponding curves for 8° fixed trim but the resulting curves contained so many uncertainties that they have been omitted. They did seem to show, however, that the same general "bunching" probably took place. Consequently, it is believed to be correct to say that at the higher speeds near take-off the spray strips have little or no effect on the trimming moments.

The effect of the spray strips on the trimming moments may be seen also in the effects on the free trims at different speeds as shown in figure 9. Here the free trims assumed by the models at speeds of 12, 15, 18, 20, and 25 feet per second are plotted against the widths of the spray strips with the angle of the strip to the horizontal as a parameter. For each speed the curves are prolonged to the trim at that speed without spray strips.

These curves show that in general the width of the spray strip has a greater influence on the trim alone than the angle at which it is set and that paralleling the results from the fixed trims the effect of the spray strips in reducing the trim increases from a speed of 12 feet per second to 15 feet per second and then falls off until it becomes practically negligible at 25 feet per second.

The appearance of the curves suggests that it would be possible to draw straight lines, representing coarse approximate means of the three curves for each of the various speeds, from a focus at some width—apparently near 1 inch—to the trims with no spray strips. This result, in turn, suggests that if the spray strips, or the

deflecting planes of the bottom, were made about 1 inch wide, or about 6 percent of the beam, the model might be found not to change trim between 12 and 25 feet per second and might travel at a constant trim of about 3° for the whole of the take-off run. The possibility will be investigated of making a model hold a constant trim, of itself, through the take-off run by fitting a suitable spray strip. It is understood that the phenomenon has been observed in tests in other tanks.

From the foregoing it follows that the addition of the spray strip, especially at the greater widths and larger angles, will tend to reduce the positive trimming moments during the earlier stages of a take-off and, in particular, should reduce the speed that must be reached before the aerodynamic controls of a flying boat can become effective in controlling attitude.

CONCLUSIONS

The conclusions drawn from this series of tests are, of course, strictly applicable only to the model tested and at the load and speeds used. They should apply quite well, however, to hulls of generally similar form operated at loads and speeds that give approximately the same load and speed coefficients.[1]

Spray.—There appears to be no criterion for efficiency in suppressing the spray. Opinion based upon observation must serve for the present. It is believed that spray strips having a width of from 2 to 3 percent of the beam and set at angles of from 30° to 45° below the horizontal at the step give the best reduction in the spray from the condition found with no spray strip. Apparently the width might be increased with improved suppression, but supporting the strips would become a problem.

Based upon observation during these tests it is believed that spray strips generally should extend farther forward than those tested on this model—if feasible, right around the bow—and that the downward angles near the bow should be not less than those corresponding to those used with the 45° setting.

Rise.—The effect of spray strips on the rise probably may be neglected, although it is real and can be observed in the model tests.

Resistance.—The general effect of the spray strips is to reduce the resistance at speeds below and at the hump. In free-to-trim runs the addition of the spray strips causes the model to trim lower and rise a little more. The combined effect is a reduction in resistance. In fixed-trim runs the trim is maintained but a smaller moment is required to hold the trim while the rise is increased. The combined effect again is a reduction in resistance. At higher speeds, and especially near the get-away speed, the resistance is either about the same as without the spray strips or is slightly increased. The wider strips (2.25 to 3 percent of the beam) at 30° to 45° downward angle give more reduction in resistance at the lower speeds and cause no more resistance than the narrower strips at any angle. At speeds near get-away the resistance at the low trim angles (4° to 6°) is affected only slightly by fitting the wider strips at the greater angles.

Moments.—At speeds in the neighborhood of the hump the addition of spray strips introduces a consistent negative trimming moment. The wider (2.25 to 3 percent of beam) and steeper (30° and 45°) spray strips produce a greater effect at the lower speeds. The reduction in the positive trimming moment thus obtained should make the aerodynamic controls become effective earlier in the take-off run.

At speeds near the get-away the change produced by adding the spray strips is relatively slight. The effectiveness of the aerodynamic control of the full-size craft should not be disturbed by the small increase n the negative value of the moments.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *June 15, 1934.*

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[1] These coefficients, with the resistance and trimming-moment coefficients, are defined as

Load coefficient $C_\Delta = \frac{\Delta}{wb^3}$

Speed coefficient $C_V = \frac{V}{\sqrt{gb}}$

Resistance coefficient $C_R = \frac{R}{wb^3}$

Trimming-moment coefficient $C_M = \frac{M}{wb^4}$

where Δ, load on the water, lb. (or kg)
R, water resistance, lb. (or kg)
w, weight density of water, lb. per cu. ft. (or kg/m ^{3})
(For the N.A.C.A. Tank w= 63.6 lb. per cu.ft.)
b, beam of hull, ft. (or m)
M, trimming moment, lb.-ft. (or kg-m)
V, speed, ft. per sec. (or m/s)
g, acceleration of gravity, ft. per sec.^{2} (or m/s ^{2})

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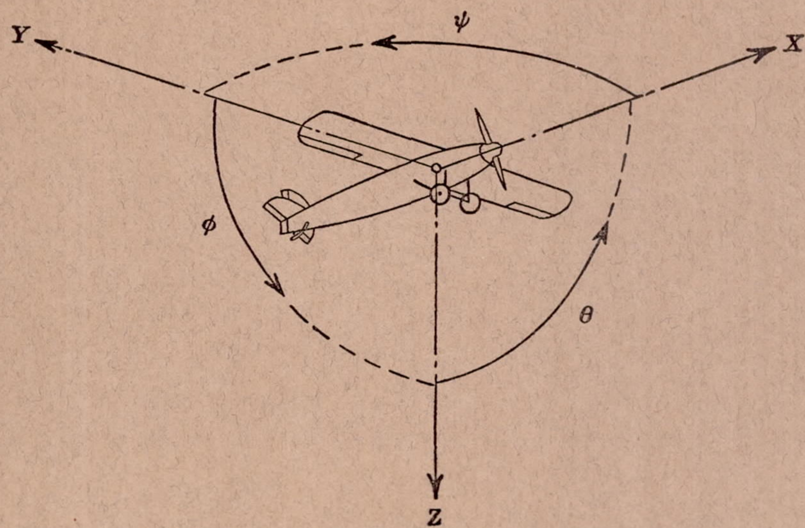

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	Rolling	L	$Y \longrightarrow Z$	Roll	ϕ	u	p
Lateral	Y	Y	Pitching	M	$Z \longrightarrow X$	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	$X \longrightarrow Y$	Yaw	ψ	w	r

Absolute coefficients of moment

$C_l = \frac{L}{qbS}$ (rolling) $\quad C_m = \frac{M}{qcS}$ (pitching) $\quad C_n = \frac{N}{qbS}$ (yawing)

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter
p, Geometric pitch
p/D, Pitch ratio
V', Inflow velocity
V_s, Slipstream velocity
T, Thrust, absolute coefficient $C_T = \frac{T}{\rho n^2 D^4}$
Q, Torque, absolute coefficient $C_Q = \frac{Q}{\rho n^2 D^5}$

P, Power, absolute coefficient $C_P = \frac{P}{\rho n^3 D^5}$
C_s, Speed-power coefficient $= \sqrt[5]{\frac{\rho V^5}{P n^2}}$
η, Efficiency
n, Revolutions per second, r.p.s.
Φ, Effective helix angle $= \tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 hp. = 76.04 kg-m/s = 550 ft-lb./sec.
1 metric horsepower = 1.0132 hp.
1 m.p.h. = 0.4470 m.p.s.
1 m.p.s. = 2.2369 m.p.h.

1 lb. = 0.4536 kg.
1 kg = 2.2046 lb.
1 mi. = 1,609.35 m = 5,280 ft.
1 m = 3.2808 ft.